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EFFECTS OF CRUDE OIL ON POLAR BEARS

SUMMARY REPORT

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EFFECTS OF CRUDE OIL
ON POLAR BEARS

SUMMARY REPORT

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1. Introduction

It is widely perceived that accidental oil spills and oil well blow outs may occur in arctic marine areas as a result of offshore petroleum development and that these could have detrimental effects on wildlife populations. Although arctic research programs have contributed new knowledge on the extent or severity of such events, many aspects remain poorly understood. The impact on polar bears, Ursus maritimus, is one example. Given that hunting quotas and methods will continue to be regulated, it is the increased human occupation and disruption of polar bear living areas that present the greatest threat to this species.

There are several reasons why polar bears may be considered a sensitive species with regard to petroleum pollution. Polar bears spend a great amount of time travelling across sea ice and traverse open water leads in search of food, primarily seals. They then become particularly susceptible to under-ice spills and the effects of "herding" of oil by wind and ice action, as well as to oil spreading on top of the ice. The possibility of ingestion of oil fractions is real in that ringed seals, their main food source, are known to accumulate petroleum hydrocarbons. As a top member of the animal food chain, the polar bear may therefore receive high inputs of bioaccumulated petroleum hydrocarbons in the event of an arctic oil spill. In addition, the polar bear is an arctic species of great importance to the Canadian Inuit. It has a social significance and still serves as an economic consideration to certain native communities.

An investigative study on the effects of crude oil was conducted as part of the Eastern Arctic Marine Environmental Studies (EAMES) Program. The purpose of the EAMES Program was to carry out a comprehensive scientific investigation of the offshore and nearshore waters and their marine life in order to obtain sufficient data to prepare Environmental Impact Statements, for the east coast of Baffin Island.

The polar bear study underwent a number of changes in experimental design. As originally proposed by the investigators, the study was to examine immediate and long range effects of oil by determining the animal's ability to regulate its body temperature after immersion in oil contaminated water. The effects of oil absorbed through the skin and ingested were to be tested separately. The proposal included sacrificing under controlled conditions, some of the experimental animals and this element generated considerable negative response from the public. Therefore, the experimental design was modified following discussions with representatives from northern communities, as well as the Canadian Council on Animal Care, the Canadian Wildlife Federation, the Canadian Association of Humane Societies and the Polar Bear Care Committee. The EAMES Advisory Board, which represents several Baffin Island communities, strongly supported the study.

The redesigned experiment conducted in February 1980 at Churchill, Manitoba was to emphasize investigation of the ability of polar bears to regulate the body temperatures once their fur had been fouled by crude oil. The phases of the study which required controlled feeding of oil to the animals or their sacrifice were deleted. The thermoregulatory aspect of this investigation was deemed essential because previous studies had indicated that polar bears rely on the thermoinsulative properties of their fur and of their fat. Disruption of the polar bears' ability to regulate their body temperature in defence against the cold ambient temperature could be critical to their survival.

The impact of exposure to oil on the bears' ability to maintain their heat balance was to be related to the characteristics of Midale crude oil to its changes with exposure, and its uptake through the skin as measured by blood plasma oil levels. An ongoing health program would monitor any shifts occurring in clinical strees-related parameters. Because of the unexpected and extensive grooming activity by the bears after oil exposure and consequent

severe toxicity effects, two of the experimental animals died. Therefore, it became necessary to increase the analytical component of the study program to include further assessments of hydrocarbon residues, a more detailed clinical assessment, and a comprehensive pathology.

Results obtained from this study will now be used to predict he effects of a spill in the field and enable the implementation of preventive and corrective measures.

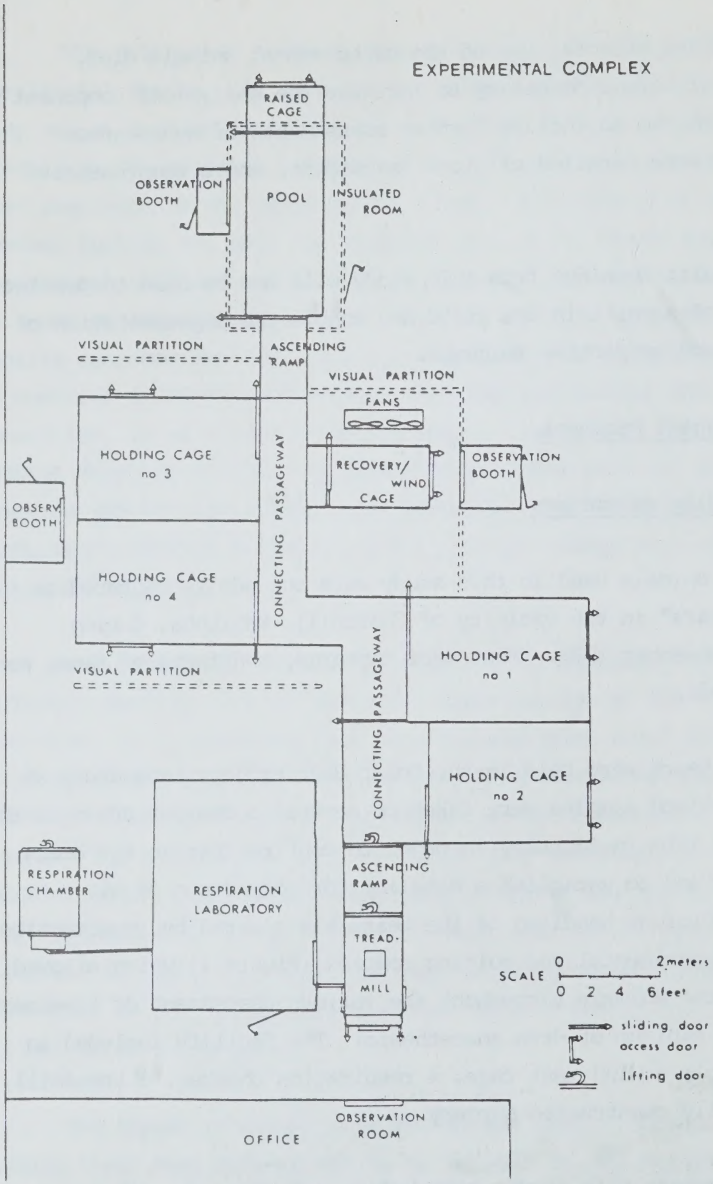
2. Experimental Protocol

2.1 Holding parameters

All animals used in this study were sub-adults captured as "nuisance bears" in the vicinity of Churchill, Manitoba, during October to November 1979. Four were captured, and three of these were exposed to oil.

The bears were held in the Polar Bear Project Laboratory at Churchill. Blood samples were taken on several occasions prior to the oil exposure late in February in order to confirm that in the bears were healthy and to establish a baseline for comparison of oil effects. Efficient handling of the bears was assured by construction of a steel experimental and holding complex (Figure 1) which allowed transfer of the animals throughout the various assessment or treatment areas with a minimum of drug anaesthesia. The facility included an immersion pool, a wind test cage, a respiration chamber, a treadmill, and a specially constructed surgery.

Throughout this study, both before and after the oil exposure experiment, the bears and the experimental protocol were under constant review by individuals and groups additional to the researchers at Churchill. Participatory representation by the Canadian Council for Animal Care, by the Polar Bear Care Committee,



igure 1. Research complex used at the Polar Bear Project Laboratory, Churchill, Manitoba.

and by the Canadian Association of Humane Societies, as well as review by representatives of Inuit through the EAMES Advisory Board assured that the project was conducted in accordance to the accepted protocol. In order to supervise the health of the polar bears, the study had regular input from veterinarians from the Canadian Wildlife Service and the Manitoba Department of Agriculture.

2.2 Exposure Regime

The oil used was a Midale crude oil which was found to resemble arctic oils in many respects. It was of medum viscosity and showed a wide range of characteristic hydrocarbon fractions. The oil was partially weathered prior to bear exposure, which resulted in some loss of the most volatile and most acutely toxic components.

The three experimental bears were each exposed in late February 1980 to a 1 cm thick slick of Midale crude oil on water in the immersion pool for a period of 15 to 50 min. The oil effects study extended for up to six weeks following exposure. This included analyses of metabolism and thermal balance, blood sampling to assess health status, and attempts at cleaning of the oil-fouled fur (Figure 2). By this time, two of the bears had become seriously ill and died. Determination of the physiological factors associated with their condition allowed an effective therapy to be carried out on the other bear when it was transferred at the end of March to the Assiniboine Zoo, Winnipeg, Manitoba.

2.3 Study Methods

2.3.1 Heat Balance

Skin and deep body temperature measurements of the polar bears were made by temperature sensitive radiotransmitters surgically implanted about 2 weeks prior to oil-exposure measurements, two transmitters per animal. Gas analysis was carried out on the air

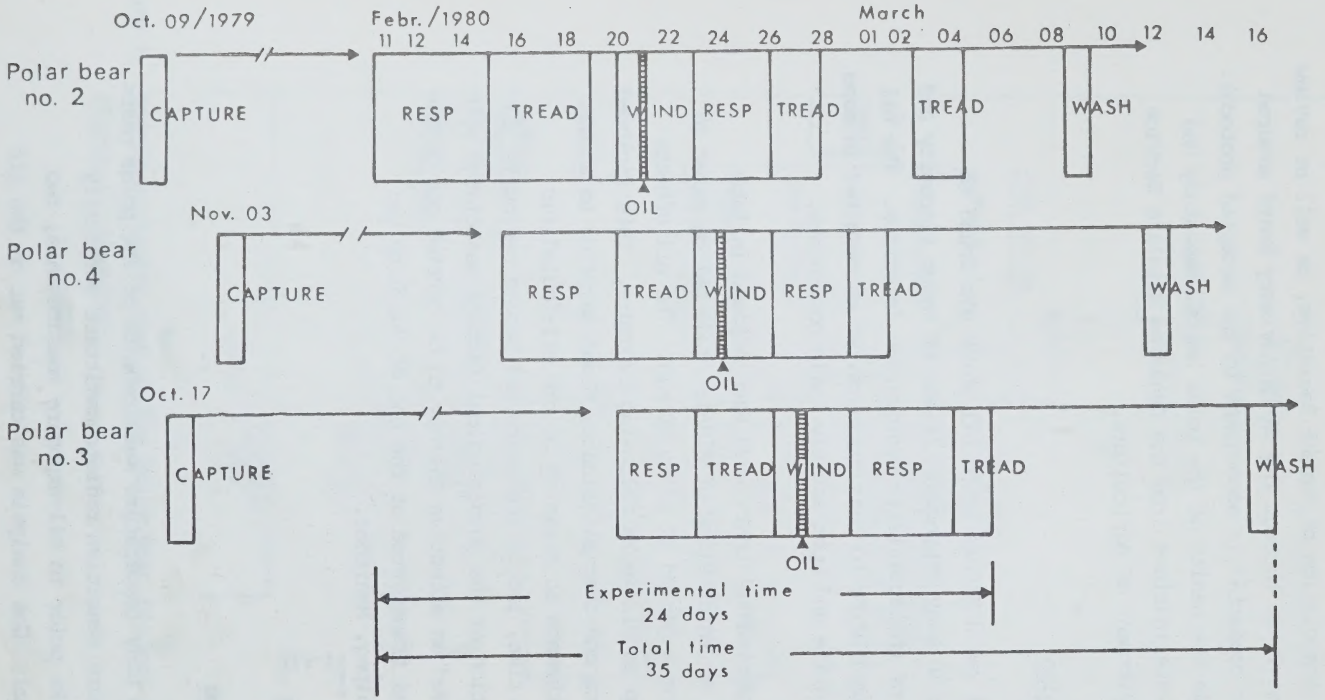


Figure 2. Schedule of experimentation for 3 oil-exposed polar bears.

flows through the respiration chamber and the treadmill chamber, allowing measurement of metabolism under conditions of relative rest and during exercise. Treadmill exercise was at a walking speed of 5.4 km/hr. Correlations between thermal balance and changes in the insulative properties of fur after oiling were tested in a wind chamber at a wind speed to about 18 km/h. Temperature measurements were made regularly during all of the experimental tests.

Detailed in vitro studies were carried out on pelt samples from the mid-back region of three polar bears, obtained through the cooperation of the Government of the Northwest Territories and the Manitoba Department of Renewable Resources. Fur conductance measurements were made using a specially designed low turbulence wind tunnel facility, capable of assessing heat flow in a variety of physical conditions, accounting for wind of different speeds and from various directions, and for solar irradiation. Heat flow was assessed with each pelt sample before and after coating of the fur with oil. Three types of oil of different viscosities were used including Midale crude oil. Coating of the pelt was achieved by immersion of only the fur in a 1 cm thick slick of oil on water for 30 min.

A computer simulation model of heat balance was derived from physiological laws, modified by correction factors for heat balance and exercise effects obtained experimentally in this study from the three polar bears, as well as the in vitro tests of fur conductance. One purpose of such a heat balance model was to describe in predictive terms changes in thermal relationships resulting from oil exposure, allowing for a range of physical variables presumed to affect thermal and metabolic balance.

2.3.2 Oil Characteristics and Residues

A detailed analysis was carried out on Midale crude oil. Both fresh and weathered crude oil were assayed for fractional composition by gas chromatography, as well as by u.v. spectral absorption and

spectro-fluorescence. The latter assays permitted determination of the concentration of total petroleum-derived hydrocarbons in a large number of biological samples, such as blood (plasma), urine, bile and tissues. Representative samples of vomitus, feces, and fur were also analyzed by gas chromatography for oil residues.

2.3.3 Clinical and Toxicological Assessment

The clinical and toxicological assessment of the effects of oil emphasized hematolog and serum biochemistry health monitors. A full spectrum of standard hematological assays was carried out on both red and white blood cell parameters.

Blood chemistry assays were conducted to assess potential effects of oil exposure on salt balance, liver function, kidney function and hormonal balance, and to maintain a regular health monitor on the conditions of the bears. Serum biochemistry was determined by standard clinical methods. When two of the bears died unexpectedly as a latent result of the oiling, the program was expanded to include gross and historpathology as investigative methods. A detailed necropsy identified which tissues or organs were primarily or secondarily affected by exposure to oil, and correlated with the clinical hematology and biochemistry findings.

3. Overview of Findings

3.1 Behaviour

When confronted with oil, the polar bears showed no obvious aversion to it. Once coated by the test slick, they actively ingested oil by licking it off their fur and occasionally from the cage walls. Overall grooming activity increased. Several hours following ingestion, the bears were observed to shiver extensively, and all three vomited for the day following exposure. Diarrhea was also evident, as was an increased thirst for the rest of the study period.

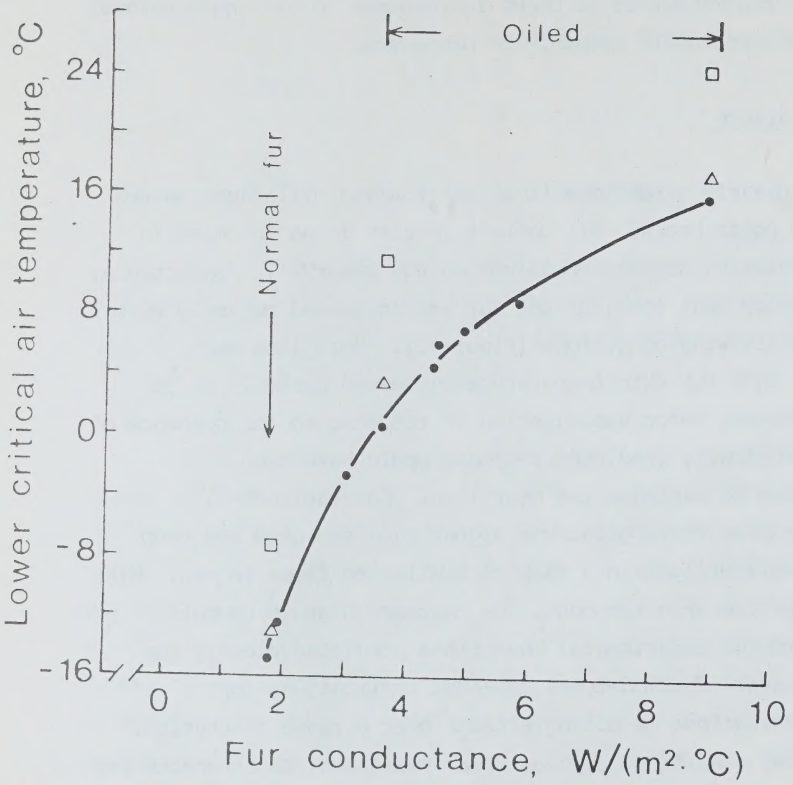
Extrapolations from the available behavioural observations to predictions of the behaviour of bears in response to oil under natural conditions, however, would probably be premature.

3.2 Heat Balance

It is clearly established that oil fouling will cause severe cold stress in polar bears. Oil contact results in an increase in metabolism, depleting readily mobilized energy reserves. Conductance, and therefore body heat loss, of the fur was increased markedly by oil coating, under all wind conditions (Figure 3). Heat loss was accentuated in that the skin temperature increased markedly as it apparently underwent major vasodilation in response to the presence of oil. A physiologically predicted response would have been vaso-constriction to minimize the heat loss. For the post-oil exercised polar bear, metabolism was higher than expected and deep body temperature increased in a fashion similar to fecer in man. With the exception of the skin response, the thermoregulatory computer model applied to the experimental conditions predicted closely the measured responses. The model has expanded applications for quantitative evaluations of oiling effects over a range of physical and physiological conditions such as solar radiation, subcutaneous fat thickness, ambient temperature, activity state, skin temperature, fever response, and animal size. As an example, the simulation model demonstrated that the lower critical air temperature for oiled bears is considerably elevated; that is, they would have to actively compensate for heat loss at even normal arctic temperatures (Figure 4). The limits of such compensation are not known at this time.

3.3 Oil Characteristics and Residues

Oil characteristic of Midale crude was found at high concentrations in vomitus and feces after immersion, and at lower concentrations in feces and stomach contents throughout the



igure 3. Fur conductance as a function of wind speed. Control values are derived from 4 pelt samples tested prior to oil contact. Furs were exposed to 3 oils: Midale crude, 10W motor oil and Base 2500 oil. All oil values are average regressions from 2nd and 3rd days after oiling.

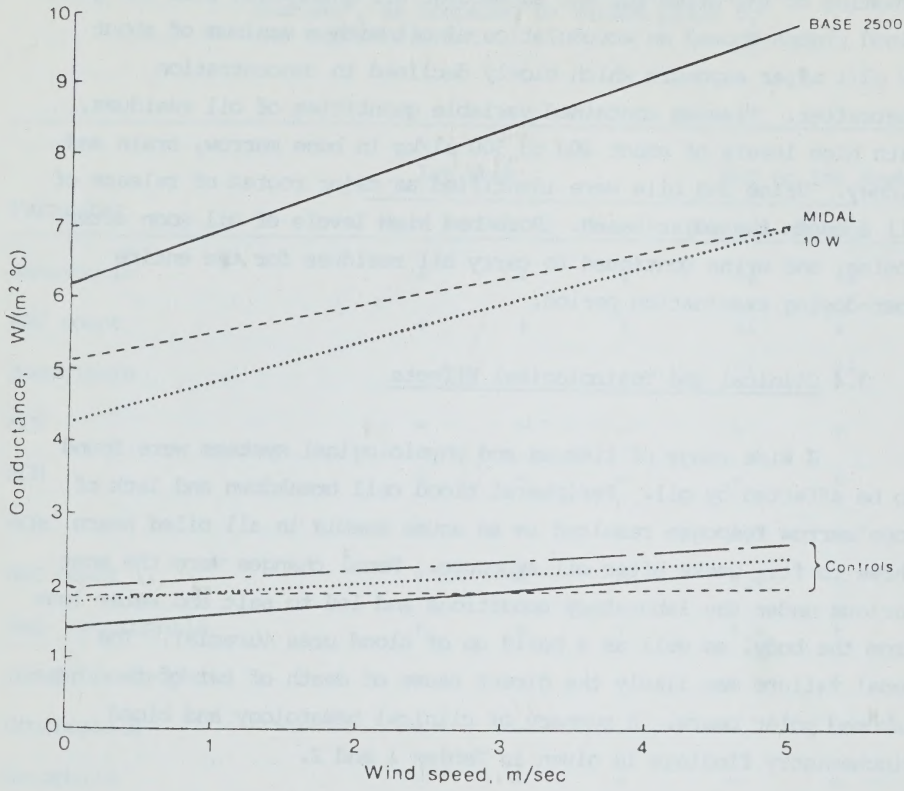


Figure 4. Simulated lower critical temperatures or polar bears of 2 body weights over a range of fur conductance values. Lower critical temperatures are presented for a 160 kg bear with fat thickness of 3 cm (.) and a 110 kg polar bear with a fat thickness of 3 cm ( ) and 1 cm ( ). Normal and oiled conductance values are derived from fur sample studies. Conditions are that the animals are at rest and that wind speed and solar radiation are equal to 0.

post-oiling period. Continued exposure probably resulted from a grooming of the oiled fur and subsequent oil absorption from the gut. Blood plasma showed an accumulation of oil with a maximum of about 30 ul/l after exposure which slowly declined in concentration thereafter. Tissues contained variable quantities of oil residues, with high levels of about 200 to 500 ul/kg in bone marrow, brain and kidney. Urine and bile were identified as major routes of release of oil load in the polar bears. Both had high levels of oil soon after dosing, and urine continued to carry oil residues for the entire post-dosing examination period.

3.4 Clinical and Toxicological Effects

A wide range of tissues and physiological systems were found to be affected by oil. Peripheral blood cell breakdown and lack of bone marrow response resulted in an acute anemia in all oiled bears three to five weeks after oil exposure. Renal changes were the most serious under the laboratory conditions and led to salt and water loss from the body, as well as a build up of blood urea (uremia). The renal failure was likely the direct cause of death of two of the three exposed polar bears. A summary of clinical hematology and blood biochemistry findings is given in Tables 1 and 2.

A wide range of tissues was found to be affected by oil, much of the effect related to the uremia and severe dehydration. Lesions were found in the upper digestive and gastrointestinal tract. Mild to moderate degenerative changes were found in brain and liver. Bone marrow and lymphoid tissue were moderately atrophied. The zona fasiculata of the adrenal cortex was hyperplastic and there was degeneration of the zona arcuata, fitting respectively with a stress response and a possible inadequacy of adrenal hormones for salt and water balance. The lungs were partially collapsed and the histological findings were suggestive of a lung surfactant deficiency. Some skin and fur changes were evident, including thickening of the skin and patchy loss of hair.

Table 1. Summary of the effects of oil exposure on hematological parameters, showing relative changes*, as compared to values prior to the exposure event.

Parameter	1st Week			2nd to 5th Week		
	Bear 2	Bear 3	Bear 4	Bear 2	Bear 3	Bear 4
Hematocrit	↓	↓	↓	↓↓	↓↓	↓↓
RBC count	↓	↓	↓	↓↓	↓	↓
Hemoglobin	=	↓	↓	↓↓	↓↓	↓↓
MCV	=	=	=	↓	↓	↓
MCH	=	=	=	↓	↓	=
MCHC	=	=	=	↓,↑	↓,↑	↑
WBC count	↑	=	=	↑,↓	=	=↓
Seg. neutrophils	↑	=	↑	↑,↓	↑	↓
Immat. neutrophils	=	=	=	↓	↓	=
Eosinophils	=	=	=	=	=	=
Basophils	=	=	=	=	=	=
Lymphocytes	↓	↓	=	↓,↑	↓=	=
Monocytes	=	=	=	=	=	=

*
↑↑ increase
↑ possible increase
= no change
↓ possible decrease
↓↓ decrease

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Table 2. Summary of the effects of oil exposure on blood biochemical parameters, showing relative changes*, as compared to values prior to the exposure event.

	1st Week			2nd to 5th Week		
Parameter	Bear 2	Bear 3	Bear 4	Bear 2	Bear 3	Bear 4
Na^{+}	↓	↑	=	↓↓	↓↓	↓
K^{+}	=	=	=	↓	=	=
Ca^{++}	=	↑	=	=	↑	↑
$PO_4^{\equiv}$	=	=	=	↑	↑↑	↑↑
$Ca^{++}/PO_4^{\equiv}$	=	=	=	↓↓	↓↓	↓↓
Urea nitrogen	↓	↓	=	↑↑	↑↑	↑↑
Creatinine	=	=	=	↑↑	↑↑	↑↑
Uric Acid	=	=	=	↑	=	↑
Total bilirubin	=	↑	=	↑↑	↑↑	↑↑
Total protein	=	↑	=	↑↑	↑	=
Glucose	=	=	=	=	=	=,↓
Cholestrol	↓	↑	=	↑↑	↑↑	↑↑
GOT	↑	=	=	=,↑	=	↑
GPT	↑	=	=	=,↑	=	=
Alk. Phos.	↑↑	↑	=	=	=	=
LDH	↑↑	↑↑	=	↑↑	↑↑	↑↑
Cortisol	↓	↓	↑	↑↑	↑↑	↑↑
Triiodothyronine	↑	↑	↑	↑	=,↑	↑↑
Thyroxine	=	=	=	=,↓↓	=,↓↓	=,↓↓

*
↑↑ increase
↑ possible increase
= no change
↓ possible decrease
↓↓ decrease

There was good agreement among clinical hematology and biochemistry findings and the results of the gross and histo-pathology. It is particularly important to note that the clinical expression of the toxicity effects was latent, not becoming pronounced in all oiled bears until three to five weeks after initial contact with the oil.

3.5 Therapy

Recovery of the surviving bear was complete, after intensive and prolonged therapy. When the bear arrived at the Assiniboine Park Zoo, it was in serious and deteriorating condition, also showing signs of severe anemia and renal failure. Treatment was aimed at maintaining urinary flow and reducing anemia, correcting salt and water problems, encouraging appetite, and inducing a positive metabolic state by providing calories.

As a result of this study, the information generated would minimize the risk that polar bears would again be lost during similar exposure experiments with crude oil. Further, close monitoring during recovery of one bear allowed a preliminary assessment of treatment strategies in the event of accidental exposures.

Cleaning the fur of the experimental animals was visually successful, but also raised concern regarding the timing and the possible disadvantages inherent in drugging weakened polar bears. Additionally, the logistical difficulties of mounting a capture and cleaning operaton in the North are obviously great, particularly should a number of bears be affected at the same time.

3.6 Conclusions

The general conclusion which may be drawn from this study is that the individual polar bear may be greatly affected when exposed to oil spills. An initial effect of coating with oil is that

thermoregulatory and metabolic stresses develop which may cause serious disability if protracted in the wild. Oil fouling of the fur led to grooming and licking of the oil from the fur, with consequent ingestion of the oil, and absorption into the body from the gut. Residence of oil in the fur may be expected to be long if the animal is not cleaned completely, prolonging exposure by grooming/ingestion activities. Uptake of petroleum hydrocarbons and their distribution to body tissues led to behavioural abnormalities and tissue damage.

4. Recommendations

Based on the findings of this study, the following general recommendations can be made to minimize the effects of oil on polar bears. In view of the serious effect of oil contact, the primary and obvious recommendation is to keep bears away from areas of an oil slick. If bears are coated with oil the animal should ideally be immobilized and cleaned immediately after exposure. If exposure was not recent, and thus it must be assumed that the bear had groomed and ingested a quantity of oil, the animal should again be immobilized, cleaned, assessed for health status, and treated as appropriate before release. How such contingency plans may be implemented was not within the scope of this study, and should be resolved through administrative action.

There are important aspects to the effects of oil on polar bears which were not addressed in this study and a number of recommendations for future studies are in order.

Priority should be given to studies of polar bear behaviour in response to oil in a relatively natural environment. A large enclosure is envisioned for such studies, facilitating observation with minimal disturbance. The bears' behavioural reactions should be tested in response to oil on sea-water, and to oil contaminated seal offered as food. Although some behavioural observations were made in this study, the program was not designed to test behavioural changes,

nor can it be assumed that the behaviour of bears in captivity was necessarily representative.

Concurrent laboratory studies should be performed, with the objective of resolving the problems revealed by this study concerning potential fever and skin reactions to crude oil. The question of whether oil may cause fever in polar bears was recognized but could not be fully analyzed in the present report. Any fever effect has important implications for handling procedures of oil contaminated animals, and should be pursued by further experimentation. Also relevant to thermoregulaltion, and not carried out in this study, is an assessment of the thermal properties of fur samples coated with oil and subjected to cold air temperatures. Such experimentally derived information on thermoregulation and metabolism should be incorporated into the simulation computer model. In any case, this model should now be exploited, based on available information, to predict the effect of oil coating in polar bears under a variety of physiological and physical conditions not specifically tested in this experimental study.

Although it has been identified that oil spill exposure is detrimental to polar bears, it has not been possible to address in any way the effects of oil spill dispersants. The use of oil dispersants may be anticipated in a spill situation, particularly if such an accident were to occur in a sensitive area.

In summary, polar bears have been found to be environmentally sensitive with regard to oil spills, resulting from their physical, behavioural and physiological characteristics. Effective contingency planning will need additional information, particularly on polar bear behavioural responses to oil.